Phytoplankton Community Responses to Nutrient Changes

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Nutrients

Elements, such as nitrogen (N), phosphorus (P), silicon (Si), iron (Fe), others, which are required in small amounts for synthesis of essential cellular constituents, for example, protein, ATP, Si frustules, chlorophyll

Forms of Nutrients in Water

- N
  - nitrate NO_3^-
  - ammonium NH_4^+
  - particulate N
  - dissolved organic N
- P
  - phosphate $P0_4^{-3}$
  - particulate P
  - dissolved organic P
- Si
  - silicate SiO_3^{-2}
  - biogenic Si
- Trace metals

Forms in the Cell (Particulate)

- N
  - Protein
  - DNA/RNA
  - Chlorophyll
  - Chitin (glucosamine)
  - High energy compounds--ATP, etc
- P
  - DNA and RNA
  - Lipids
  - High energy compounds (ATP)
  - Storage compounds (polyphosphates)

Silicon (Si)

- Used for external or internal skeleton
- Maybe required for cell division

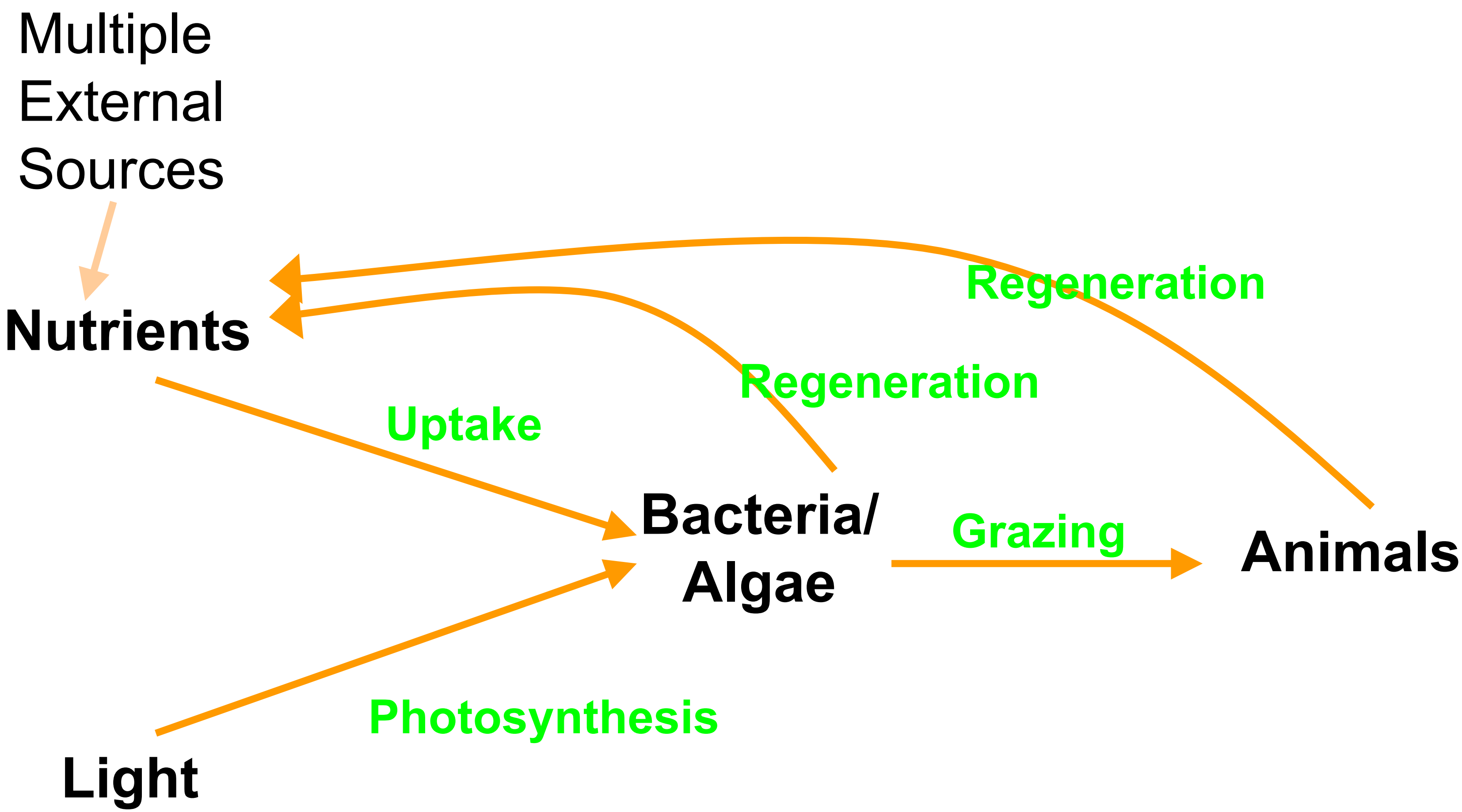
Diatom **Radiolarian**

Photographs of diatom and radiolarian

http://www.marbot.gu.se/SSS/Chaetoceros_curvisetus.htm

141.20.244.254/pal/MicroP/Amagnif.htm

Nutrient Cycle



Nutrient Limitation
Algal Growth

- Plenty of light/too few nutrients
- Marine systems--usually N limiting
- Freshwater systems--usually P limiting
- Coastal areas and estuaries--usually N, but can vary between N, P, and Si or be multiple limitations

Assessing Nutrient Limitation

- Nutrient concentrations and ratios
- Particulate ratios
- Bioassays
- Changes in species composition, e.g. diatoms not diatoms for Si
- Specific methods
  - Enzyme presence, e.g. alkaline phosphatase for P
  - Presence of compounds, e.g. ferredoxin/flavodoxin for Fe

1. P and Si limitation, and sometimes multiple limitation have all been identified at many times and places in the MAR plume. The system is in stoichiometric balance, so that any nutrient can become limiting.

N generally limits overall productivity in the MAR system. N limitation occurs most often at higher salinities and during low flow periods.

3. P limitation is much more likely than was originally expected. It occurs most often at intermediate salinities and during periods of high fresh water input.

4. The occurrence of Si limitation appears to be more spatially and temporally variable than P or N limitation. Si limitation is more prevalent in spring than summer.

5. Not all phytoplankton are limited by the same nutrient. This is intuitively obvious for differences between diatoms and non-diatoms, but also occurs at the species level.

7. There is considerable variation in the degree, kind and seasonality of nutrient limitation, which is related to variations in riverine input, but also to conditions and weather in the outflow area.

Why worry about nutrient limitation when eutrophication means that there is too much nutrient?

Eventually some nutrient runs out. If the negative impacts are so great that it is necessary to reduce nutrient loads, the limiting nutrient is the one that should be reduced.

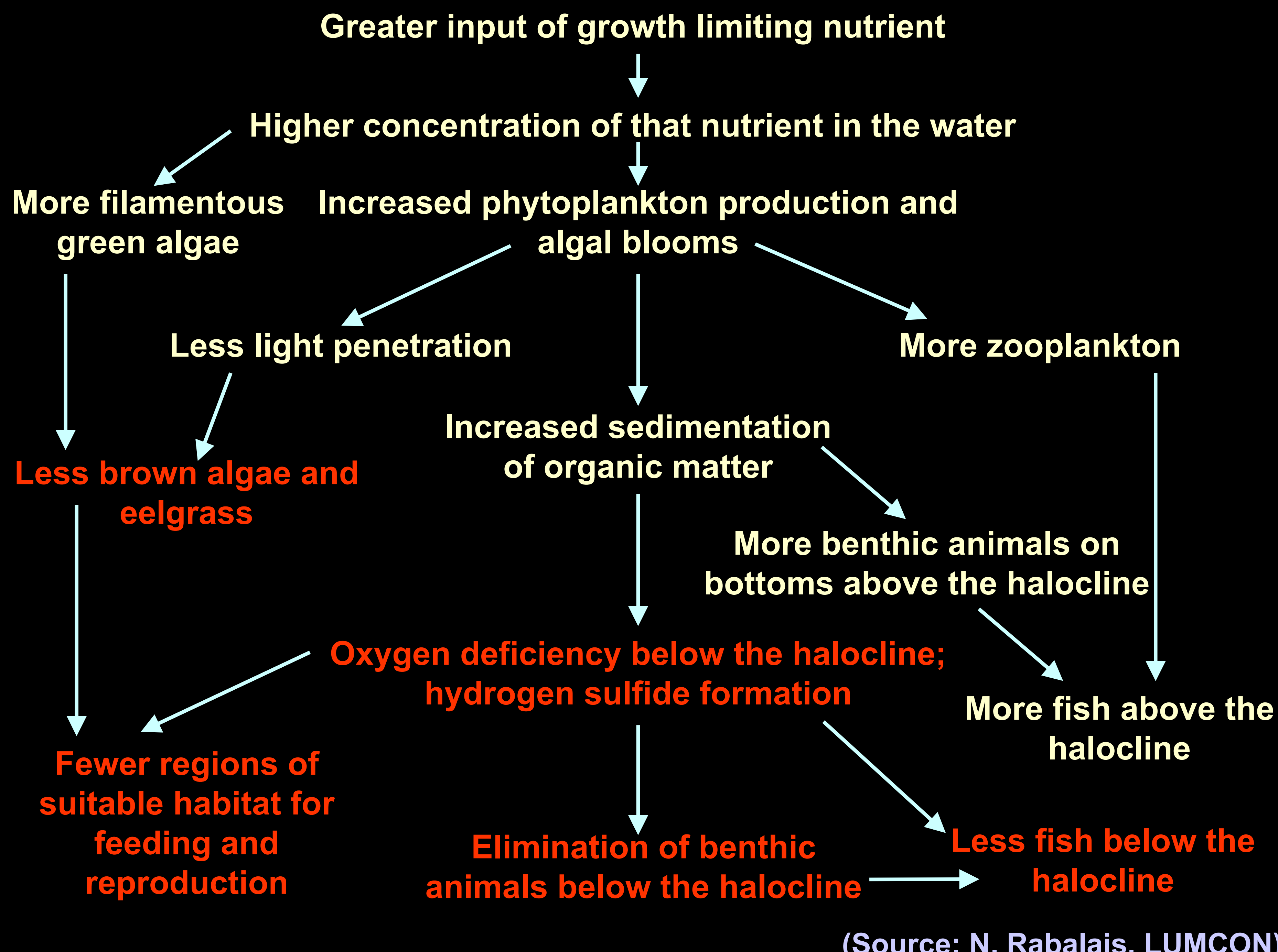
Eutrophication in Marine (MAR) and Freshwater (FW) Systems

- Much better understood in FW
- Spatial scale of causes and problem much greater in MAR
- Hydrography much more complicated in MAR
- N often limiting in MAR; P often limiting in FW

Why is this so important?

If N really is the limiting nutrient, but efforts to reduce nutrient loading focus on P, then considerable money will be spent with no effect on eutrophication.

What happens if you increase nutrients in an area with a shortage of nutrients?


Greater input of growth limiting nutrient
Higher concentration of that nutrient in the water
More filamentous green algae
Increased phytoplankton production and algal blooms
Less light penetration
More zooplankton
Increased sedimentation of organic matter
Less brown algae and eelgrass
More benthic animals on bottoms above the halocline
Oxygen deficiency below the halocline; hydrogen sulfide formation
More fish above the halocline
Fewer regions of suitable habitat for feeding and reproduction
Elimination of benthic animals below the halocline
Less fish below the halocline
(Source: N. Rabalais, LUMCON)

Consequences of Increased Nutrient Inputs

May Increase Algal Growth

- Positive Impact: increase productivity at higher trophic levels, i.e., greater fisheries yields, up to a point
- Negative Impact--eutrophication
  - Hypoxia
  - Harmful Algal Blooms
  - Degradation of coral reefs

Nitrate in San Francisco Bay Showing a 7-fold increase from 1950 to 1980

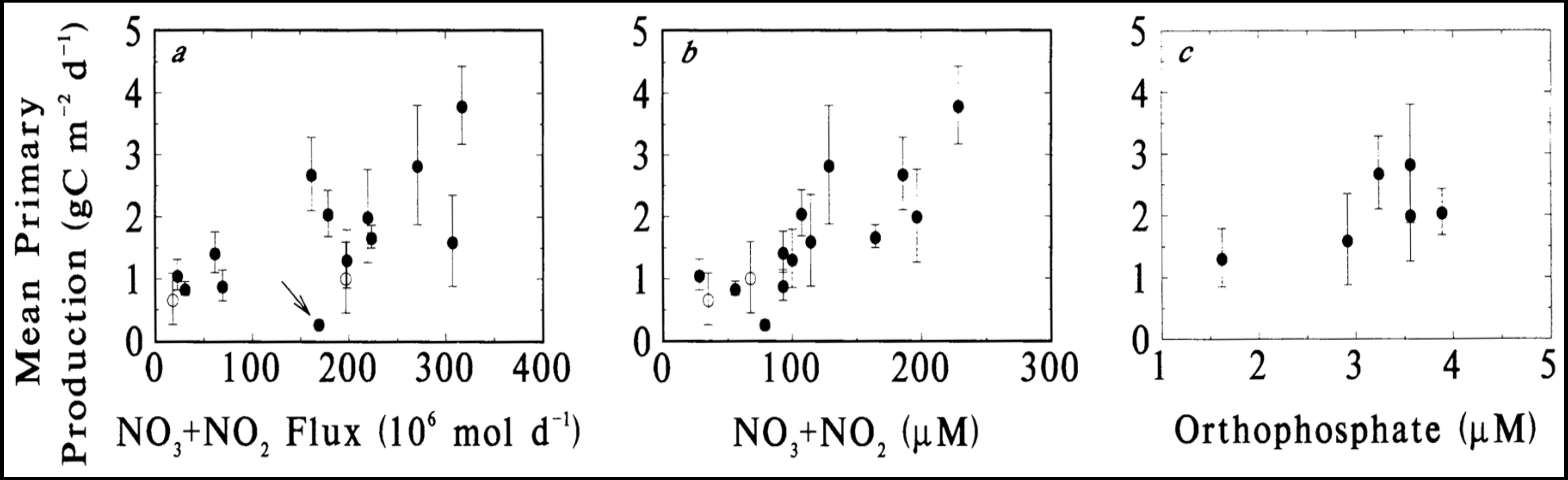
sfbay.wr.usgs.gov/access/variability.html

Delaware River Nitrate

Showing a 7-fold increase from 1910 to 1990

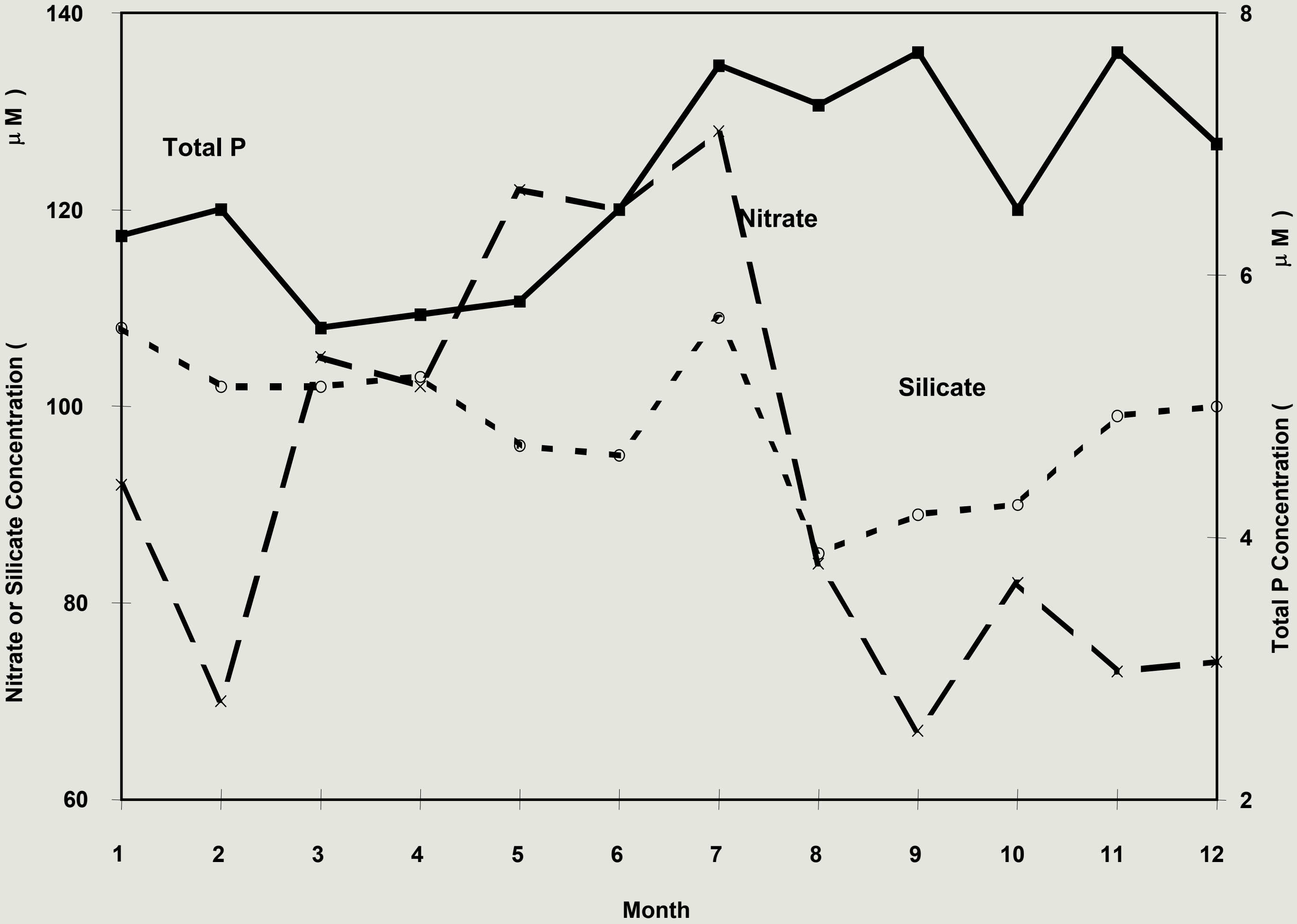
www.udel.edu/courses/mast482/lecture1.html

Nitrogen, phosphorus (and silica) are essential for the growth of phytoplankton. Most often, however, problems with an overabundance of nutrients in marine systems are the result of excess nitrogen rather than phosphorus.



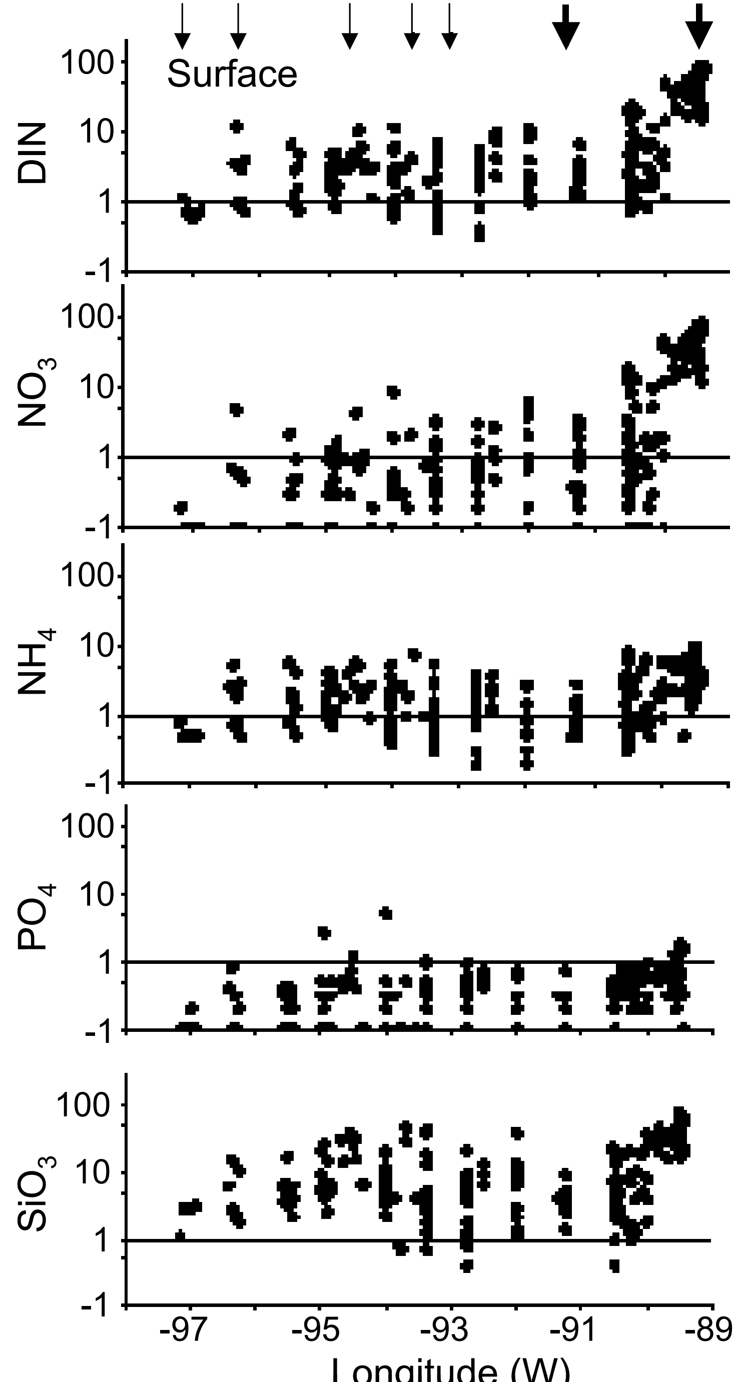
(Lohrenz et al., 1997)

Monthly NO_3, Si, TP (μM) (1975-1985)
Mississippi River at St. Francisville, LA



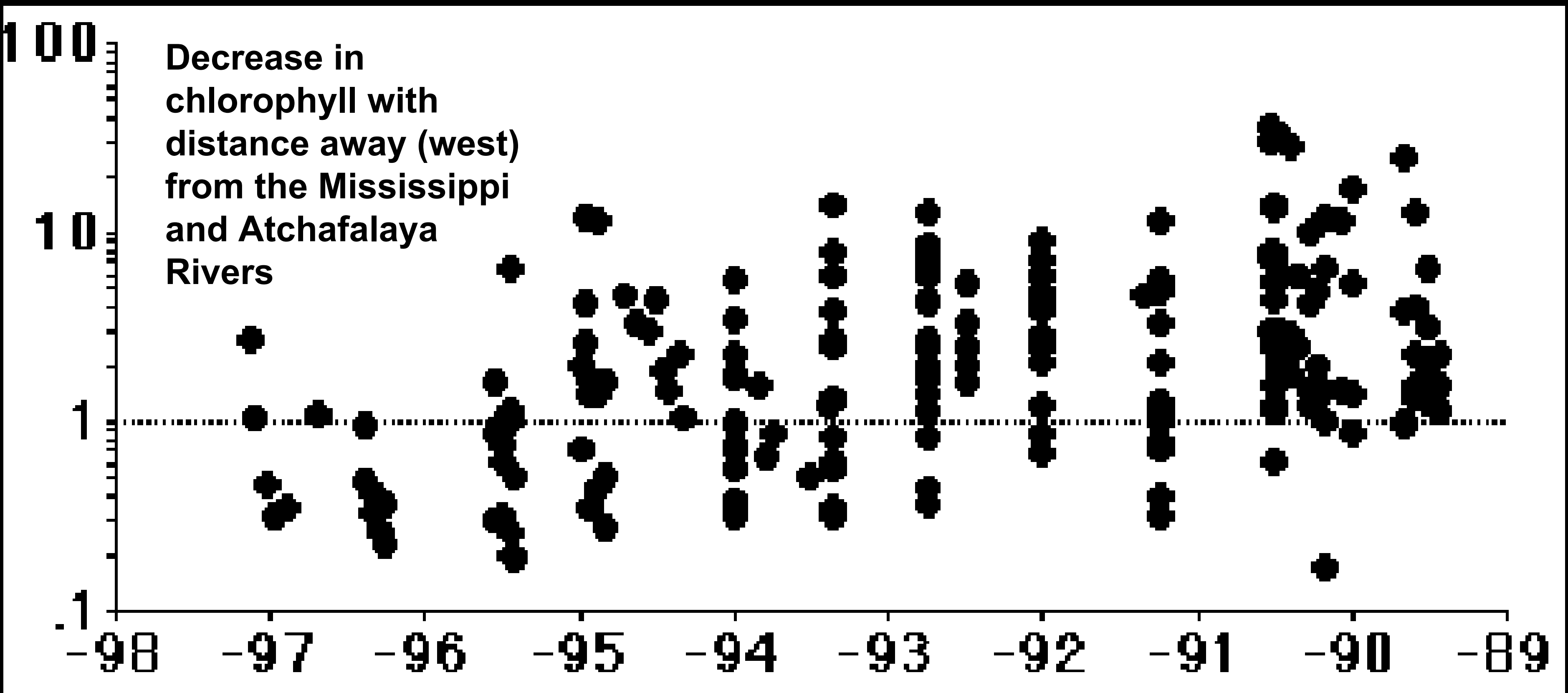
(redrawn from Turner & Rabalais, 1991)

Decrease in nutrient concentrations with distance away (west) from the Mississippi and Atchafalaya Rivers



(Rabalais et al. 2002)

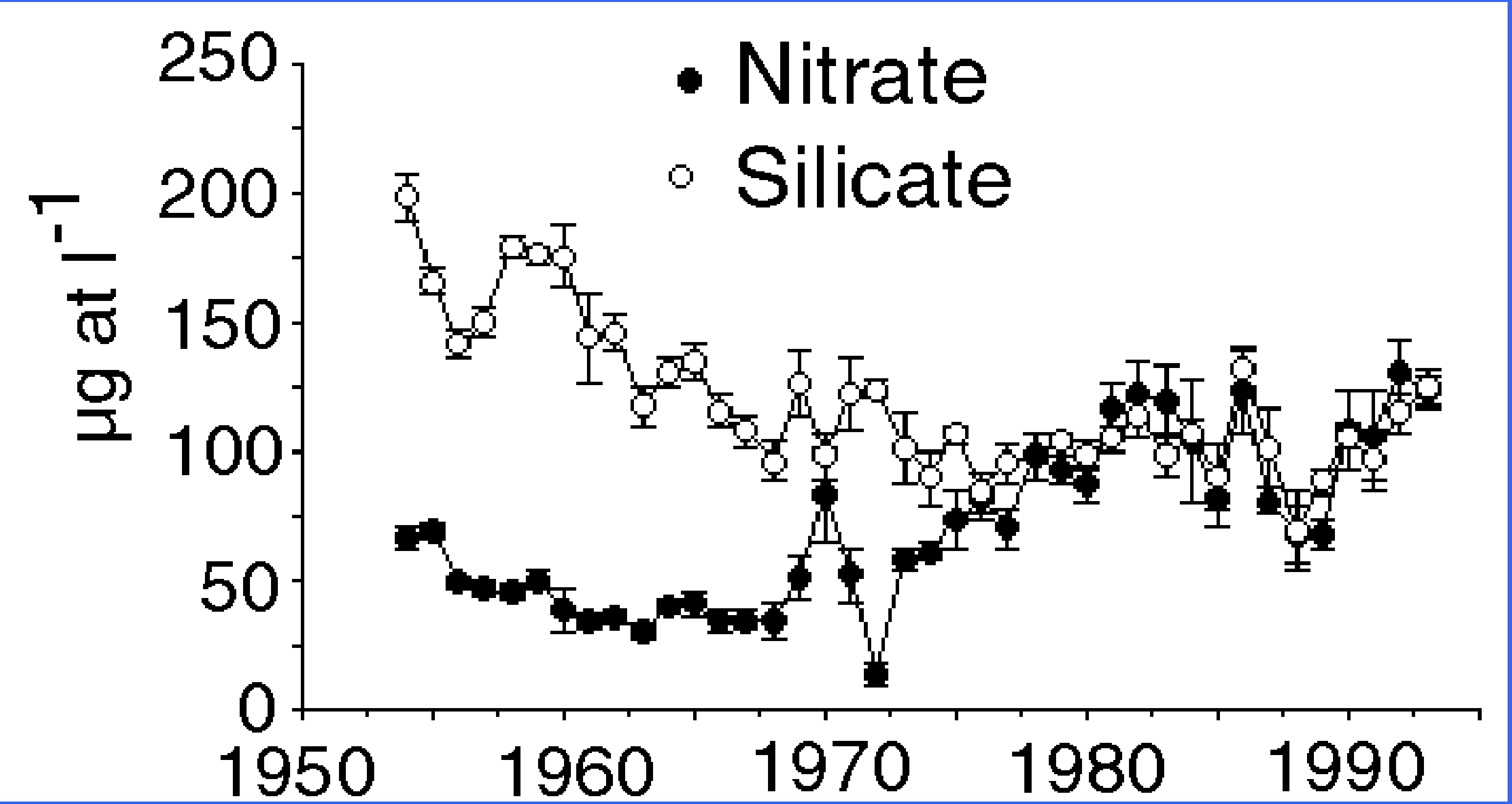
Surface Chlorophyll a (μg/l)



Longitude (W)

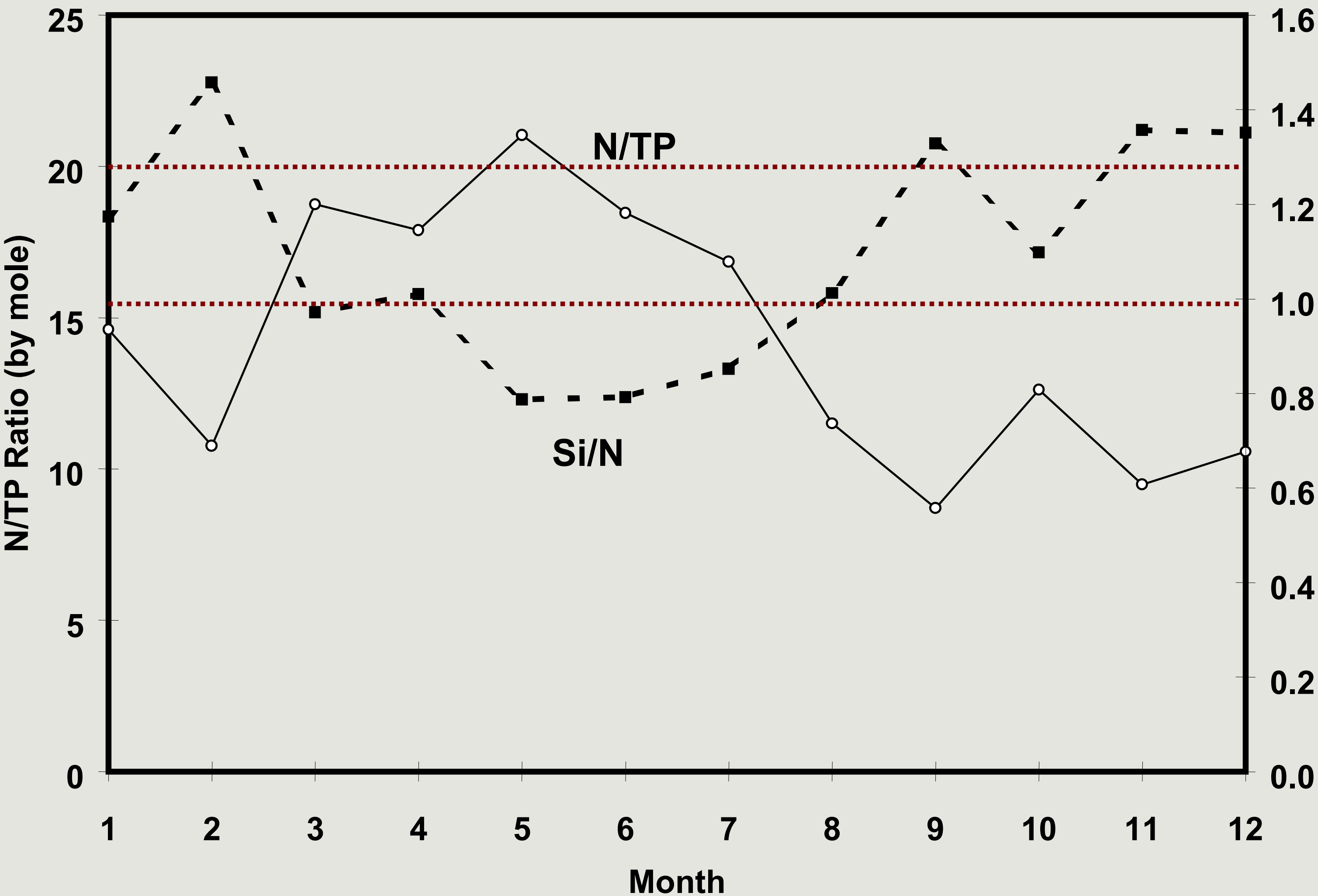
Rabalais et al. 2002

Water quality changes in the Mississippi River at New Orleans



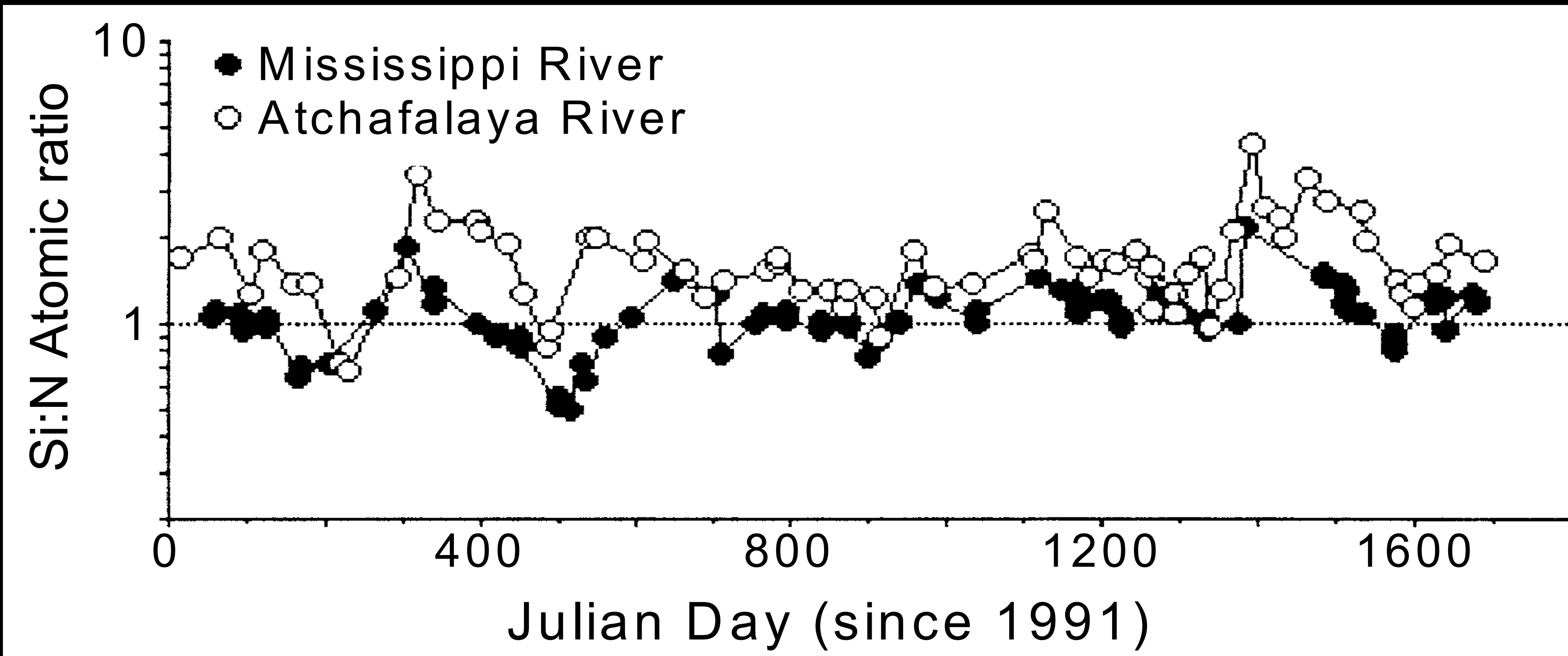
Turner and Rabalais 1991

Monthly Nutrient Ratios (1975-1985)
Mississippi River at St. Francisville, LA



(drawn from data in Turner & Rabalais, 1991)

Elemental ratio of Si:N lower Mississippi River and Atchafalaya River (1991 through September 1995).

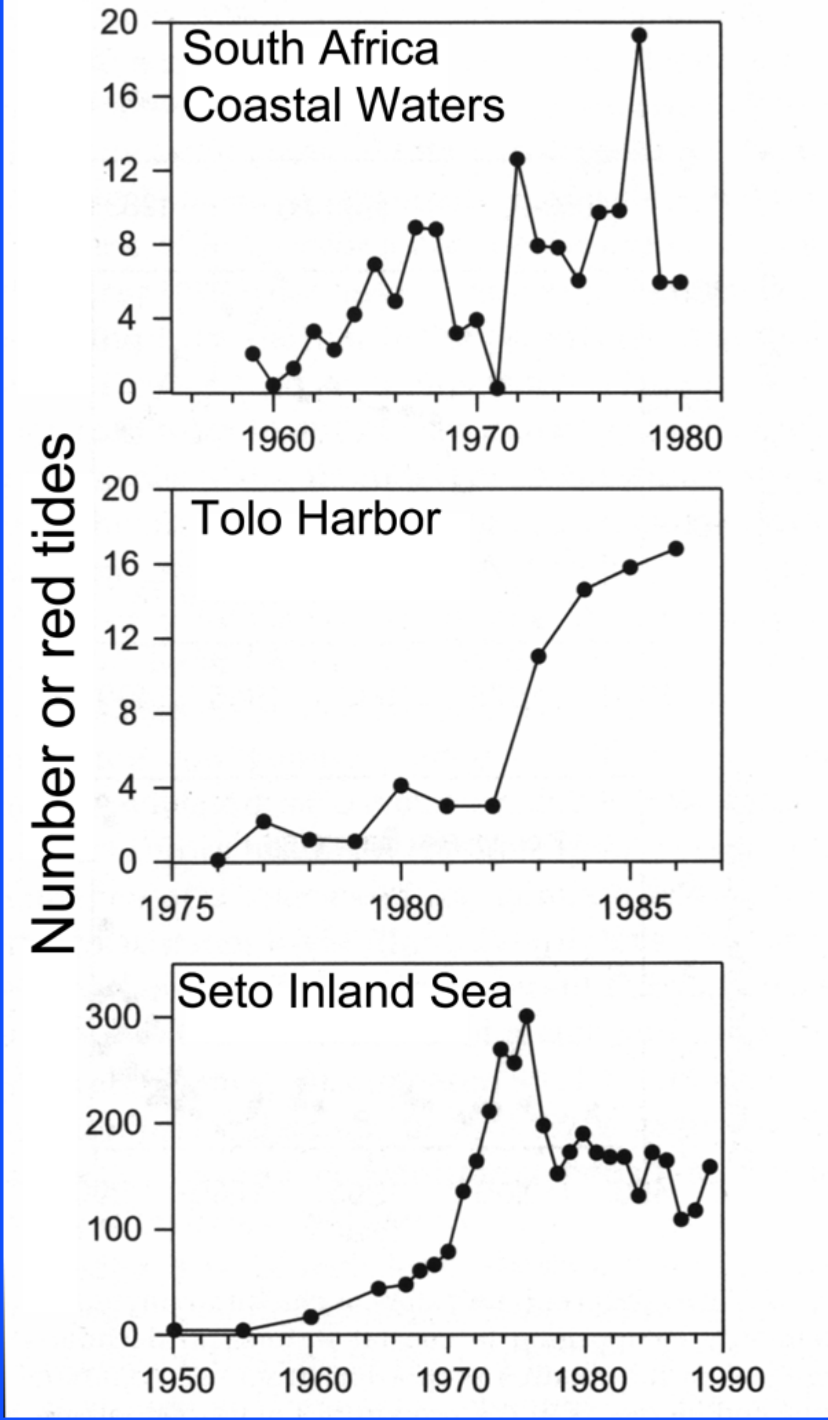


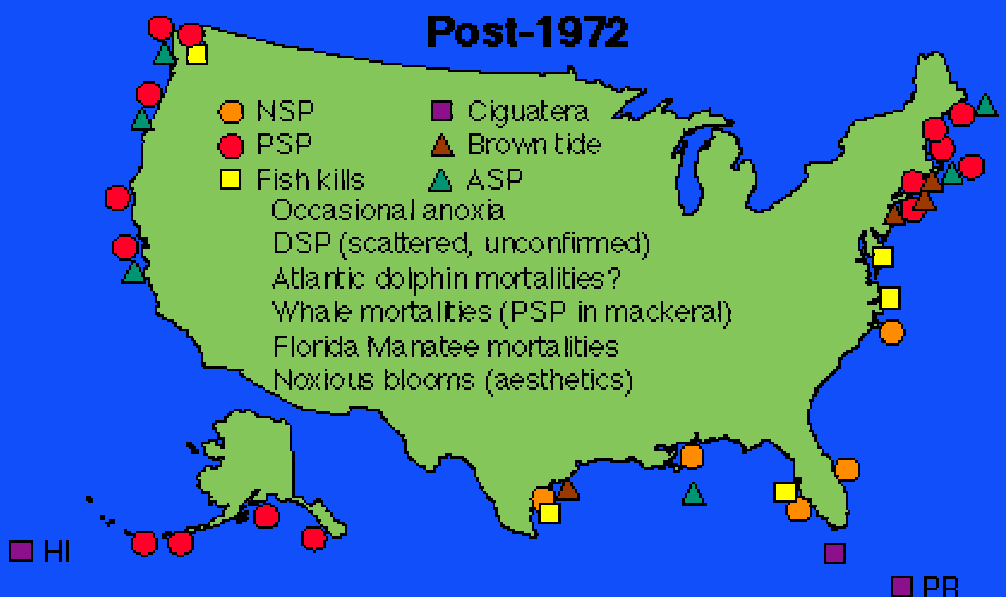
Source: Turner and Rabalais
Data are from the USGS annual water quality reports.

Officer and Ryther's Hypothesis

Si:Din > 1:1	Si:Din < 1:1
diatoms as prey	flagellated algae, incl. harmful algal blooms
zooplankton as predators	zooplankton reduced
desirable fish community	undesirable or reduced fish stocks

Incidence of red tides – parallels increase in nutrient loads





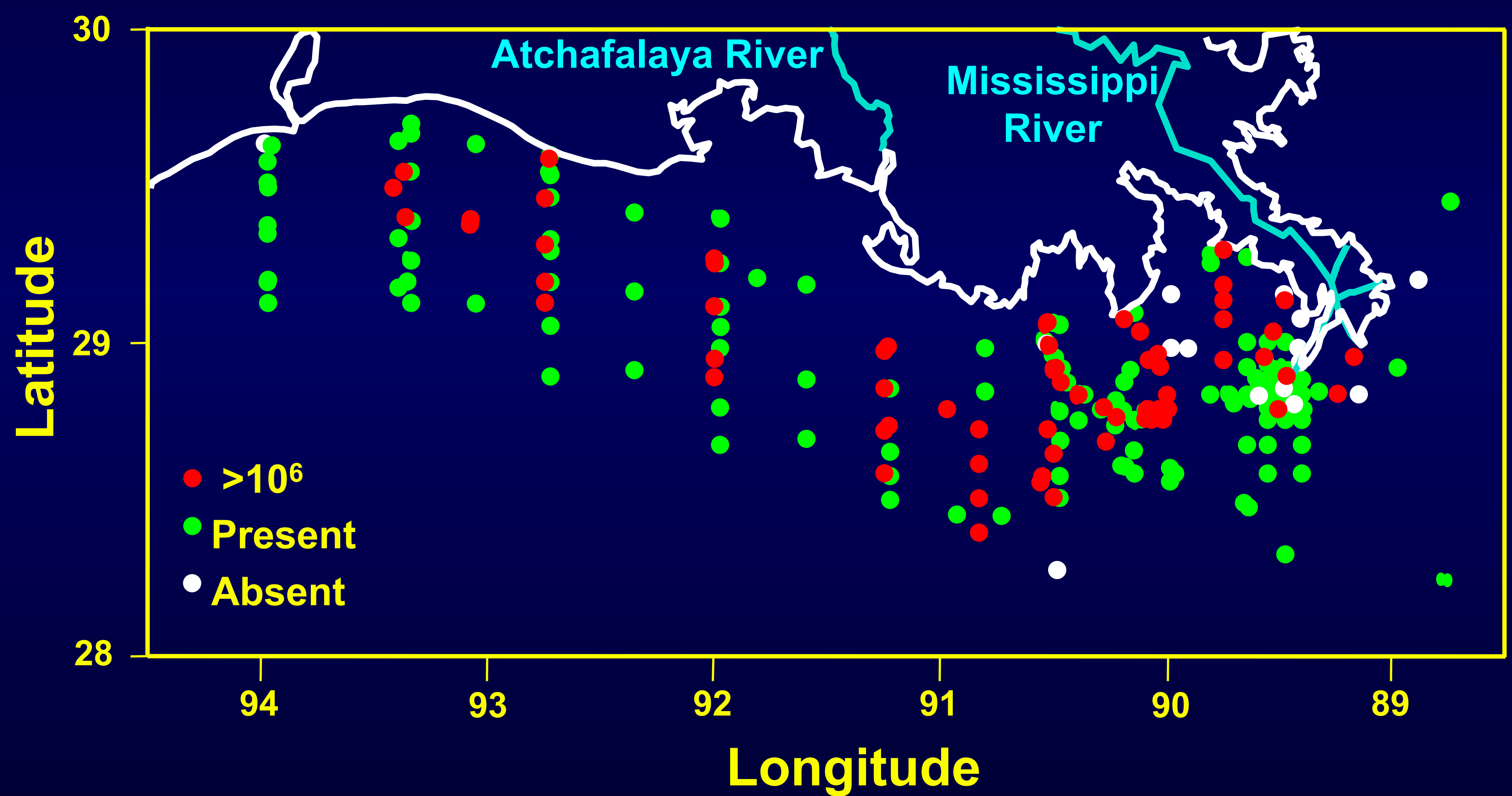
(Cloern, 2001)

Pseudo-nitzschia
Diatom

Some Forms are Toxic, Contain Domoic Acid, which causes Amnesiac Shellfish Poisoning

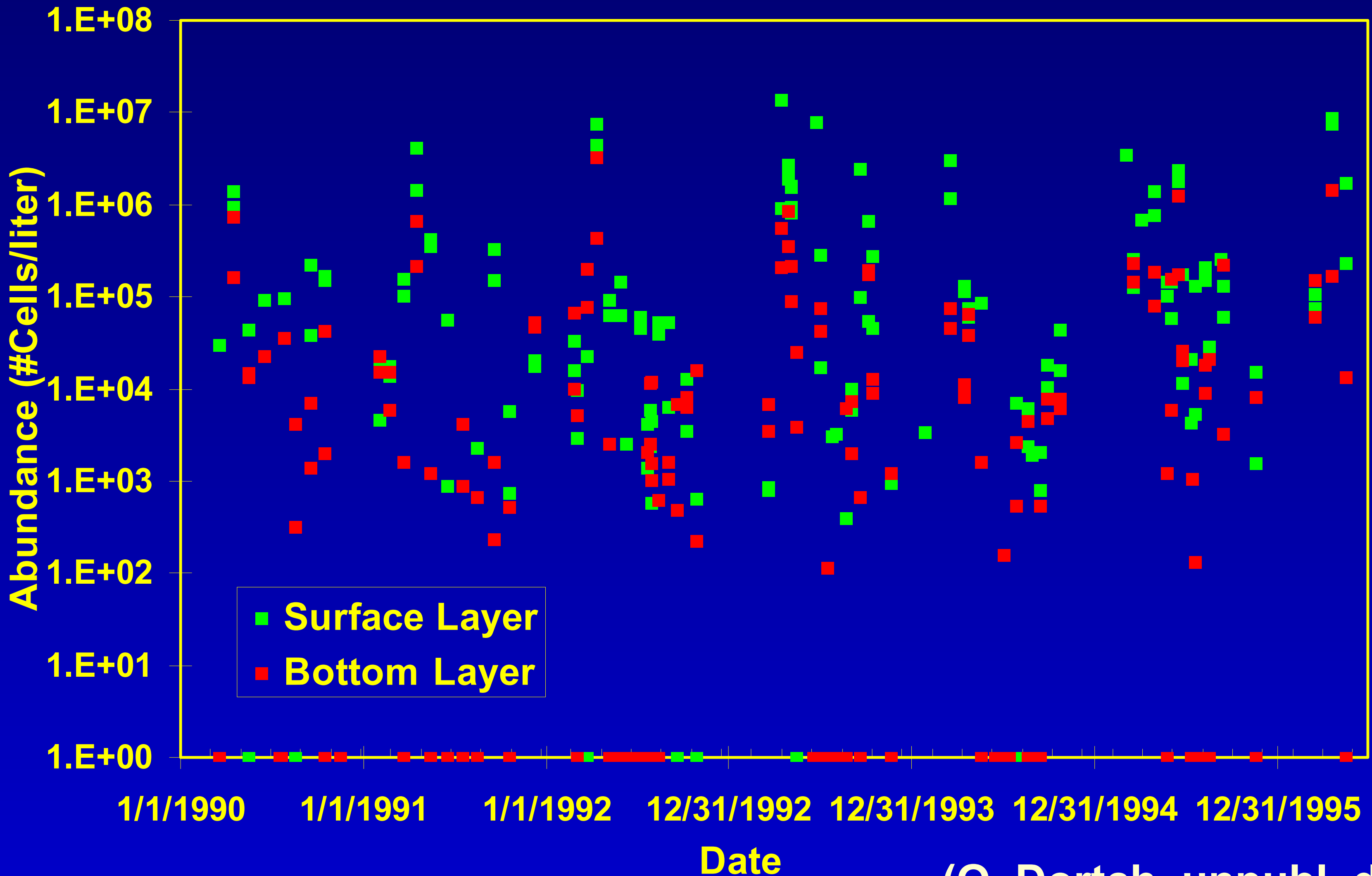
www.imb.nrc.ca/imb/poison_e.html

Pseudo-nitzschia spp. Abundance Spring 1990-1994

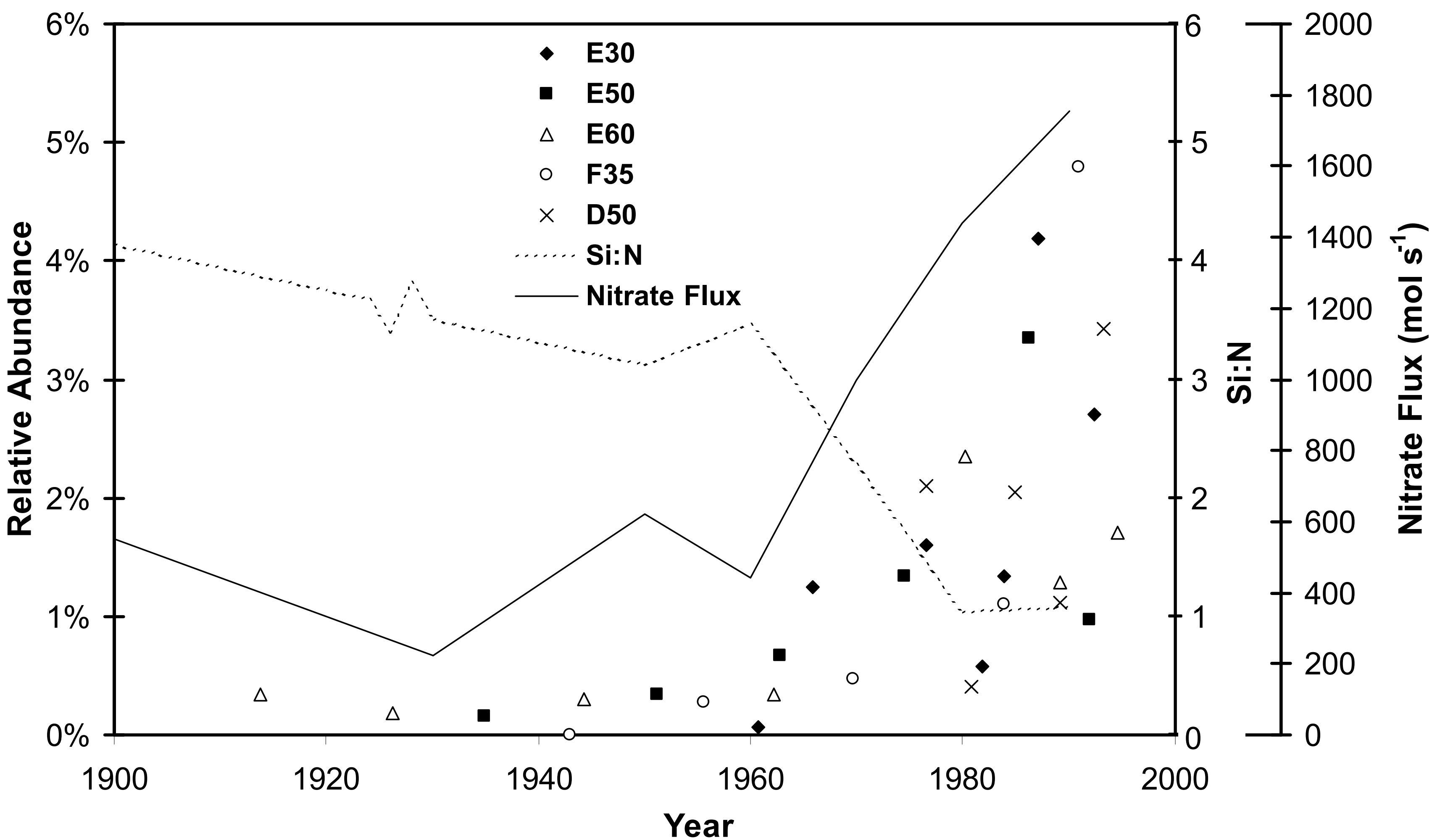


Dortch et al., unpubl .

Pseudo-nitzschia spp.
Shelf 1990-1996



(Q. Dortch, unpubl. data)



Pseudo-nitzschia in sediment cores from continental shelf just west of the Mississippi River, shows increase with increase in Mississippi River nitrate flux, despite reduction in Si:N ratio; data replotted from Parsons et al. 2002.

Lake Pontchartrain Bloom Aerial Images

Photographs of Noxious and Toxic Cyanobacterial Bloom in Lake Pontchartrain following diversion of 80 uM nitrate Mississippi River water through the Bonnet Carre diversion in spring 1997 into 5 uM nitrate concentration of Lake Pontchartrain

Photographs by R.E. Turner, LSU

Summary

- Nutrients are required for algal growth
- Algae are the base of the food chain
- Nutrient availability often limits algal growth in the ocean
- Increasing nutrients increases algal growth
  - Positive: increased productivity higher trophic level
  - Negative: increased eutrophication
- Nutrients inputs have increased due to human activities
- Changes in nutrient ratios cause shifts in phytoplankton communities and subsequent trophic linkages